PATENT SPECIFICATION

(11) 1 201 664

NO DRAWINGS

1 201 664

(21) Application No. 4183/68 (22) Filed 26 Jan. 1968
(31) Convention Application No. 92 667 (32) Filed 26 Jan. 1967 in
(33) France (FR)
(45) Complete Specification published 12 Aug. 1970
(51) International Classification G 02 b 27/38
(52) Index at acceptance
G2J 33B

(54) A METHOD OF DETECTING AND/OR MEASURING THE DISPLACEMENT OR DEFORMATION OF AN OBJECT

(71) We, COMPAGNIE GENERALE D'ELECTRICITE, of 54 rue la Boetie, Paris (8e), France, a French Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of detecting and/or measuring the displacement or deformation of an object.

The measurement of the displacement or deformation of an object can present certain difficulties, especially if one does not provide fixed marks nearby, the precision of the measurements being able to be only of the same order as or even less than the displacement.

The problems of safety posed by constructive works in particular necessitate, especially in the case of dams, checking—continuously or periodically—their behaviour which can consist for example in measurements of stress or of possible displacement of the work. The measurements of displacement are long, delicate operations, which are effected, in general, by methods of optical sighting which do not always allow of obtaining the desired precision, either because of the difficulties of replacing the apparatus in the same position at each measurement, or else because of the actual precision of the measurements which can render unreliable the measurement of displacements of the order of a millimetre, for example, even by triangulation methods.

In another connection, it is known that one can take a hologram of one or several objects, a hologram being the photographic recording of the interference systems produced between the light diffracted by the various points of the object or objects and a reference beam. The interference conditions necessitate that the beam illuminating the object and the reference beam be produced from the same spatially coherent source. This source must be strictly monochromatic if one wishes to "holograph" solid objects, because only then can one achieve the equality of the path of the reference beam and of the light diffracted by the object for all the points thereof. The plate used for the recording must have the greatest possible resolution in order to be able to reconstruct the points of the object distant from the reference beam; in fact, the interference fringe depends on the angle between the reference beam and the direction in which one sees the relevant point considered from the photographic plate. The source used can be a laser functioning either continuously or intermittently. The beam is divided into two parts: the one illuminates the object, the other directly illuminates the photographic plate. One can then, starting from a hologram, reconstruct the original information both in amplitude and in phase; thus, for example, the hologram of a three-dimensional object will allow of reconstructing this object in its three dimensions and at the position where it was with respect to the hologram during the recording.

According to the present invention there is provided a method of detecting and/or measuring the displacement or deformation of an object comprising taking a hologram, from a fixed point of the object and a reference mark, then after an elapse of time, taking from the same fixed point, another hologram of the object and the reference mark, and reconstructing and comparing the two holograms to detect and/or measure the displacement and/or deformation of the object.

A method of detecting and/or measuring the displacement or deformation of an object in accordance with this invention will now be described in more detail.

The taking of a hologram is effected by

placing at time 1 the photographic plate in a given position, at a given distance from the object. It is necessary, at time 2, to replace oneself in the conditions of time 1, whether one wishes to position a hologram of time 1 for a direct comparison between the object and the reconstruction on the spot of the image provided by the hologram, or whether according to the invention one wishes to take a new hologram. To this end, one will provide on the spot at least one fixed station comprising mechanical means such as, for example, supports, rests or other arrangements for fixing the photographic plate ensuring a correct adjustment of the hologram of time 1, or of the photographic plate for taking a new hologram; the photographic plate can likewise be placed in an immovable manner in a frame which contains all the marks and rests necessary for its correct positioning on the fixed station.

Given the dimension of the objects or constructive works the displacement of which one wishes to measure, one may be led to provide the fixed station or stations at a fairly great distance from the work, of the order of 100 metres for example. In these conditions, and taking account of the fact that it is desired to measure small displacements, of the order of a millimetre or of a few millimetres, a radial displacement of the object with respect to the hologram will generally be measured with too little precision, because the "base" equivalent to that of a telemeter will be constituted only by the dimension of the photographic plate; on the other hand, a transverse or substantially transverse displacement with respect to the hologram will be measured with precision because the image of the mark integral with the object provided by the hologram will be clear, and one will see at the same time the mark integral with the object and its image; this image will be either distanced with respect to the mark integral with the object or else merged with it, according to whether or not there will have been displacement of the object. One thus sees that one is led, in the general case, to take at least two holograms at points distant from one another. The mark or marks integral with the object will have a form such that it allows the measurement of the possible displacement; this mark can consist for example of lines of different directions or parallel to one another, of different widths, the spacing between the lines likewise able to be variable.

The measurement of a possible displacement of the object can be effected, as has been said, by reconstructing on the spot the hologram taken at time 1; for that, the hologram must be illuminated with a monochromatic and coherent beam. Let us note however that the tolerance on the monochromaticity is greater than during the recording, which allows of using in the reconstruction a more powerful laser than that used during the recording. The beam illuminating the hologram must likewise have the exact direction as the reference beam had during the taking of the hologram at time 1, so that the object may be visible in the direction and at the distance where it was during the recording. If necessary, one will be able to illuminate the mark integral with the object by means of a spotlight for example, which will allow of distinguishing clearly the image of the object, thus seeing the direction of the displacement.

It is however possible that the wave-length of the radiation emitted by the laser during the reconstruction may be slightly different from the wave-length used for the recording of the hologram at time 1, and it is necessary to provide a regulation of the wave-length. Moreover, the gelatine constituting the hologram can have undergone a more or less considerable distortion, especially as a result of ambient humidity. The variation of the wave-length, the distortion, or their combination, bring about a reduction or an enlargement of the reconstructed image with respect to the object. To alleviate this difficulty, one records at the same time as the object a fixed mark independent of the object, of definite form, and one regulates, during the reconstruction on the spot, the direction and the wave-length of the beam emitted by the laser to obtain the exact superposition of the said fixed mark and of its image.

The method of reconstruction described necessitates making measurements on the spot, operations which can be fairly long and hampered by bad weather for example; moreover, if one desires to preserve the "history" of the displacement, a new hologram must be recorded at this time 2. It is then possible to use the holograms of times 1 and 2 to effect the measurement of the displacement. Thus according to the invention, one records the hologram of time 2, still with the fixed mark, without other precaution, and one reconstructs the holograms indoors for example. In fact, if the beam serving for the reconstruction has the geometric characteristics of the beam during the recording of the hologram, the object will be reconstructed life-size; but, by exploiting the divergence and the wave-length of the illuminating beam, one can enlarge or reduce the image, as well as the distance at which it is reconstructed. On the other hand, one can likewise reconstruct the object in real image which allows a direct observation on a screen for example; thus, if one reconstructs the object with a reduction, the latter will be located at a lesser distance,

which is worthy of note for considerations of space required; the precision of the measurement should be less, but this is easily rectified by observing by means of a lens, or even a microscope, in the case of a real image, or by means of a magnifying telescope in the case of a virtual image.

The reconstruction of the hologram of time 1 will allow of marking physically the positions of the fixed mark and the mark integral with the object. On the reconstruction of the hologram of time 2, one will cause the image of the fixed mark to coincide with the physical image of that mark. One will thus achieve the correct spacing of the hologram 2 with respect to the laser beam, and the regulation of the wavelength of this beam, if the wave-length of the beam at time 2 was different from that of time 1; there is no reason when operating thus to concern oneself with possible distortions which might have been produced on the gelatines of the holograms of times 1 or 2. The image of the mark integral with the object, given by the hologram of time 2, will be compared with that given by the hologram of time 1, and the displacement will be able to be measured by the means indicated above.

Another method of measuring the possible displacement of the object can be used, especially in the case of transverse displacements of the object with respect to the hologram, a case which, as already indicated, gives the greatest precision of measurement. One takes at time 1 several holograms of a fixed mark and of a mark integral with the object, causing the distance between the mark integral with the object and the fixed mark to vary, by displacements of this last, by millimetre steps for example, and keeping constant the distance between the fixed mark and the photographic plate of the hologram. One thus has a series of holograms numbered a, b, c, d, etc. corresponding to imaginary displacements of the object. At a time 2, one takes a new hologram in the conditions of the hologram *a* for example, which is possible by placing the photographic plate on the previously mentioned fixed station; then one compares the hologram of time 2 successively with the holograms a, b, c, d, etc. of time 1, and one looks for the one with which it coincides, by causing the two holograms to slide with respect to one another. This method of operation is only possible on condition that it is ensured that the beam used during the taking of the hologram at time 2 has the same direction and the same wave-length as at time 1, a condition essential for obtaining identical interference figures for the same marks. One may still fear a distortion of the gelatine of the holograms; the coincidence of the interference figures of the fixed mark allows of ensuring whether or not there has been distortion.

We may note that this method of operation does not entirely exclude recourse to the other methods previously described; it has however the advantage of providing very quickly an indication of the size of the displacement, which can allow of taking safety measures while awaiting confirmation of this displacement by one or other of the other methods.

What has been said of time 2 is naturally valid for the subsequent times 3,4, etc., whatever may be the method of measurements used.

WHAT WE CLAIM IS:—

1. A method of detecting and/or measuring the displacement or deformation of an object comprising taking a hologram, from a fixed point of the object and a reference mark, then after an elapse of time, taking from the same fixed point, another hologram of the object and the reference mark, and reconstructing and comparing the two holograms to detect and/or measure the displacement and/or deformation of the object.

2. A method as claimed in Claim 1 in which, initially a first plurality of holograms are taken, each hologram corresponding to a particular position of the reference mark, and after the elapse of time, a second plurality of holograms are taken, each of the second plurality of holograms being related to a position of the reference mark which coincides with an individual one of the positions of the reference mark during the first plurality of holograms.

3. A method of detecting and/or measuring the displacement or deformation of an object as claimed in Claim 1 and substantially as hereinbefore described.

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Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1970
Published at the Patent Office. 25 Southampton Buildings, London WC2A 1AY from which copies may be obtained.